Impact of the dryness level on the quality of fermented sausages produced by means of **Quick-Dry-Slice process (QDS process®) technology**

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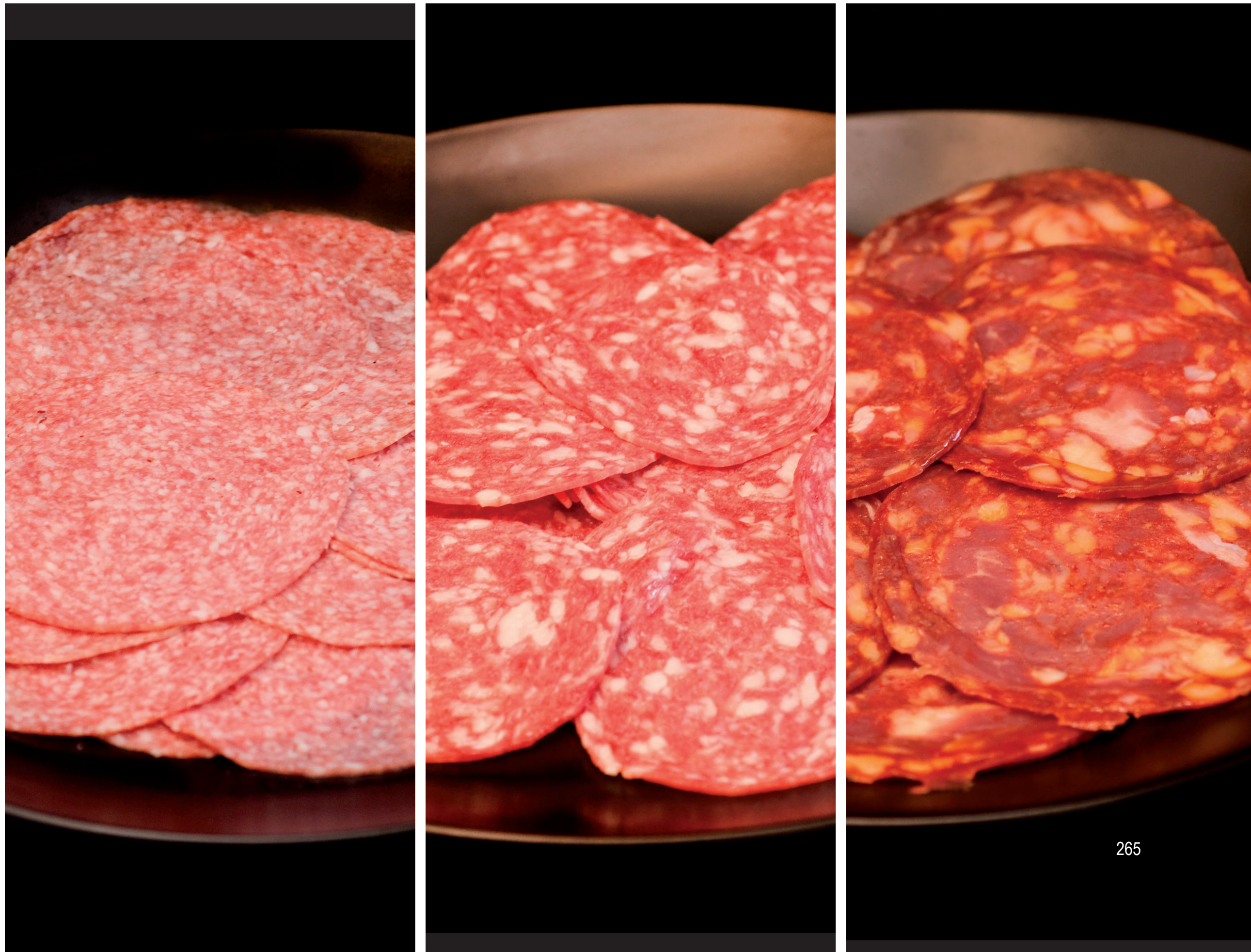


SUMMARY

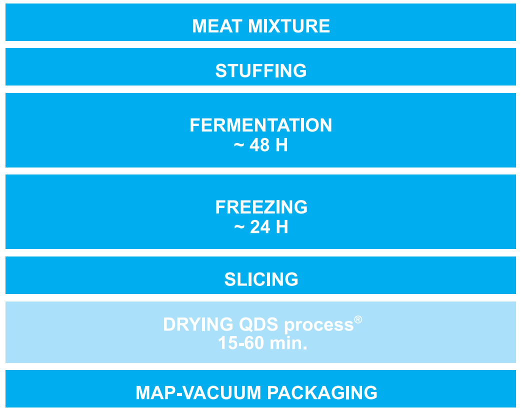
The drying period for meat products such as *chorizo* (red-pepper sausage) constitutes the slowest phase of the manufacturing process. Quick-Dry-Slice Process technology allows for drastically reducing this time and facilitates control over the product's level of dryness. Thus, the objective of this study was to evaluate the variability in quality of *chorizo* in relation to small changes in the weight loss of a dry-cured product using QDS process® technology and to compare these results with a dry-cured product using the standard processing method. *Chorizo* with a weight loss of 27, 30 and 33 % was produced by means of QDS®, and *chorizo* with a 28 % weight loss was produced by means of the standard process. The moisture content, the water activity and the pH were analyzed, as well as the color (CIELAB), the instrumental texture (relaxation test) and various sensory parameters. The results show that a difference of 27 to 33% in the weight loss of *chorizo* dried with the QDS process® makes for significant differences ($P \leq 0{,}05$) in the physicochemical parameters of color (L^* and b^*) and texture (F0), with the drier product being darker, less yellowish and tougher. The *chorizo* produced by means of the standard process has greater luminosity (L^*) (a lighter and less aged appearance) and less toughness than the QDS process® *chorizo*. Regarding sensory characteristics, the *chorizo* produced by means of the standard process obtained a slightly better valuation in texture and aromatic aspects , while the overall appearance was more favorable in the *chorizo* dried with the QDS process®. The QDS drying process® provides for better adjustment of weight loss and evolution of pH than the standard drying process, making it easier to adapt the appearance, acidity and aromatic aspects due to a better control of the process.

1.- Introduction

Dry Cured meat products are well known for their singular sensory characteristics. Traditional methods require long processing times. However, Quick-Dry-Slice Process (QDS process®) technology makes it possible to reduce this time by accelerating the drying period, which is the slowest part of the process. QDS process® technology is based on a continuous system that combines air drying and vacuum drying of the meat product's slices. Industrial implantation of the process has been carried out, in an initial stage, in the processing of fermented sausages, which can be also smoked. There is a wide variety of these products in European, America and Asian markets, each of them with its peculiarities. Some are marketed with a weight loss of only 10 %, while some reach weight losses that exceed 40 %. Each product has its optimum moisture content by which it is characterized. Some studies have reported the sensory changes resulting from different moisture contents for the same product (Ruiz-Ramírez y col., 2005a, b). The QDS process® provides for an easy adjustment of the product's weight loss by modifying the drying process in only a few minutes. The objective of this study is to evaluate the variation in quality of *chorizo* produced with QDS process® technology according to changes in weight loss during drying of the product.

1.1.- Production process with QDS process® drying

The drying technology of the QDS process® is based on a drying-maturing system proposed by Comaposada, Arnau, Gou and Monfort (2004) for sliced products, whereby the dry-cured *chorizo* undergoes a stage of fermentation until the desired pH is obtained, then are frozen until the optimum slicing temperature is reached, after which they are sliced and then dried by means of the QDS process®, which requires times of under 60 minutes depending on the weight loss desired (Figure 1).



▲ Figure 1. Diagram of the processing steps for the production of a stuffed fermented product dried by means of the "QDS process®".

1.2.- QDS process® pilot equipment

At the inception of this new technology's development, a pilot equipment (see previous article: Fast Drying of Dry-cured Meat Products Quick-Dry-Slice – QDS- Process Technology) was designed to carry out machine's trials, adjustments and improvements on a small-scale in order to build it at an industrial level afterwards. It was only the QDS drying phase, from the frozen slices loading to the vacuum-drying zone, to eliminate the water that is the most difficult to extract, including an intermediate tempering and forced-air drying zone.

1.3.- QDS process® industrial equipment

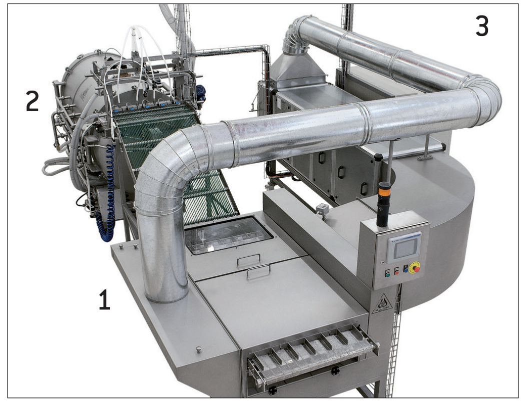
On an industrial level, the "QDS process®" cannot be understood as an isolated piece of equipment, but as an element that must be integrated in a complete line that includes slicing of the product and delivery of the slices to the nucleus of the process, which is QDS drying. Also, once dried and cooled, the slices must be overlapped in the desired format and packaged in vacuum or modified atmosphere packets .

In regard to the nucleus of the process, research with the prototype equipment has provided for the development of QDS processes that make it possible to reduce or eliminate the vacuum drying stage for most products, replacing it with a longer convective drying time, resulting in products that are equivalent to those obtained with the original QDS process®. This leads to an industrial line of greater simplicity and with reduced energy consumption.

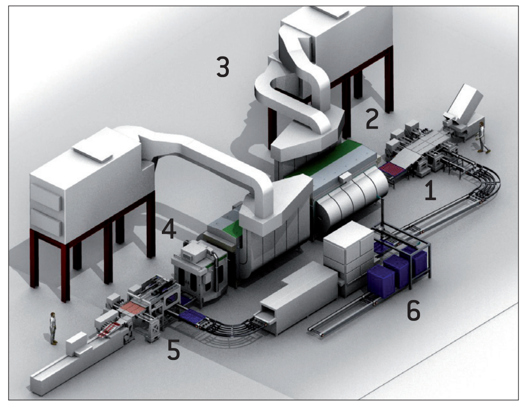
A QDS process® line with an average production capacity of 400 kg/h is illustrated in schematic form in Figure 3.

• **Slicing zone:** In this zone the bars of the frozen product are sliced and, by means of a set of conveyors, the slices are distributed on a perforated plastic tray on which the entire drying process takes place. The tray incorporates an RFID tag that provides for its identification without contact.

▼ Figure 2. "QDS process®" pilot equipment: 1. Tempering/ convective drying stage; 2. Vacuum drying stage; 3. Air processing circuit with HEPA filter.

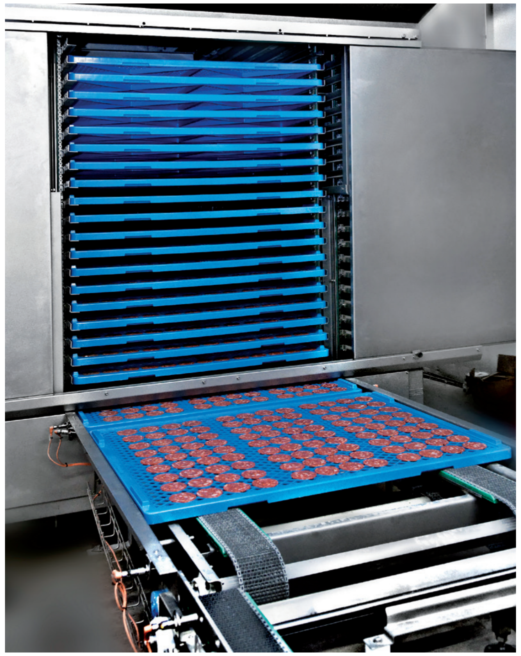


▼ Figure 3. Industrial QDS process® line developed by METALQUIMIA, S.A.U.



▼ **Figure 4:** Slicing zone with a loaded tray (Courtesy of Metalquimia, S.A.U. and Casademont, S.A.).

▼ **Figure 5:** Trays in a QDS process® drying tunnel (Courtesy of Metalquimia, S.A.U. and Casademont, S.A.).



Each tray is weighed on-line at the beginning and again once it has been loaded with slices, thereby obtaining the initial net weight.

• **Air conditioners:** One of the key points in the QDS process® stems from the fact that the short time required for drying means that this process can be performed at higher temperatures than the traditional process without altering the product's organoleptic characteristics. In fact, the upper limit of the drying temperature is determined by the melting point of the fat used in the product. These high temperatures, usually between 20 and 30 º C, make it possible to reduce to a minimum the use of refrigerating equipment in temperate or cool climate zones, replacing such equipment with mixtures of outer air recirculated to control temperature and humidity ("free-cooling"). The air conditioners in the QDS line are intelligent elements

▼ **Figure 6:** QDS process® air conditioner (Courtesy of Metalquimia, S.A.U. and Casademont, S.A.).

that automatically regulate the mixture of outer air and recirculate it, providing a typical reduction in energy consumption in temperate zones of about 30 % compared to conventional drying. In addition, they are equipped with refrigerating and heating capacity and HEPA filtering system.

• **Accumulator-Cooler:** At the output end of the QDS process® drying tunnels, the trays loaded with the product go through this zone where they receive a flow of cold air that quickly reduces the temperature of the slices, adapting them to the conditions for packaging. The accumulation tower can accept short stoppages of the thermoformer (changes of film, etc.) without altering the drying process time.

• **Packaging zone:** Final weighing takes place at the accumulator outlet, and the definitive percentage of weight loss is obtained. Then, a gantry robot removes the slices from the processing tray and places them on a conveyor to be fed into the overlapping and package formation system. The configuration of this zone is totally variable depending on the packaging format, the space available and the degree of automation desired. It typically consists of a system for overlapping the slices and formation of the portion to be packaged by means of mobile band or round belt conveyors and a system for placing the portions in the thermoformer forms, by hand, conveyor belts or robots.

▼ **Figure 7:** QDS process® accumulator (Courtesy of Metalquimia, S.A.U. and Casademont, S.A.).

Zone for washing, storage and transport of the trays: During the normal working cycle, once they have been unloaded the trays are transported by a system of conveyors to a washing, sanitation and drying tunnel, usually located in an adjacent room. From there, the clean trays are carried again by a system of conveyors to the slicing zone, where the cycle begins again. If stoppage occurs in the slicing zone or at the end of the day for the purpose of cleaning the entire line, a gantry robot collects the clean trays and deposits them in piles on a storage conveyor, where they remain until they are needed again in the slicing zone.

▼ **Figure 8:** QDS packaging zone (Courtesy of Metalquimia, S.A.U. and Casademont, S.A.).

2.- Methodology

2.1 *Chorizo* manufacture

High-quality *chorizo* (diameter: 70 mm) was used to evaluate the effect of dryness level on its sensory characteristics. The product was made following the standard industrial procedure. After fermentation, a portion of the product was frozen, sliced and dried using the QDS process®, and another portion was dried by the standard process. The instrumental color and texture were determined before and after drying. The sensory analysis was carried out after drying.
The QDS process® was used only in the convective drying stage (30 ºC and 30 % relative humidity) on

slices of 1.5 mm in thickness. To reach the different weight losses of 27, 30 and 33%, required between 33 and 43 min. The standard process was carried out at 13 ºC and a relative humidity of 70-80 % to reach a loss of 28 % in 40 days.

2.2.- Analytical methods

Surface color of the slices was measured using Minolta Chroma Meter CR-300 (Minolta, Co., Ltd., Japan) equipment. CIE Lab L *, a * b * were the parameters measured to determine the degree of luminosity, redness and yellowness. The relaxation test (SR) done by means of the universal analyzer TA.TX2 (Stable Micro system Ltd., Surrey, England), with a load cell of 5 kg and a compression plate of 50 mm in diameter allowed for determining and registering the force according to the time after a compression during 90 s (relaxation time). The relaxation curves obtained for each sample were normalized by calculating Y (t) = F0 - F (t) / F0 where F0 (kg) is the initial force and F(t) is the force registered after a pause of t seconds. The value Y at 2 s (Y2) and at 90 s (Y90) was calculated. The samples compressed by 25% of their original height with a crosshead speed of 1 mm/s.

▼ **Figure 9:** Tray cleaning and storage zone (Courtesy of Metalquimia, S.A.U. and Casademont, S.A.).

QDS PROCESS

The study also included determination of moisture content (AOAC, 1990) and water activity at 25 º C (Aqualab CX-2 . Decagon Devices, Inc., Washington, EE.UU.).

The sensory analysis was carried out by six selected and trained tasters (ISO-8586-1, 1993; ISO-8586-2, 1994) (ISO-8586-1, 1993; ISO-8586-2, 1994). The descriptors were defined in three previous sessions. The descriptors selected were: intensity of color, acidic flavor, intensity of characteristic *chorizo* flavor and toughness. A non-structured scale of scoring was used (Amerine et al., 1965), where 0 means absence of the descriptor and 10 means a high intensity of the descriptor. The sensory evaluation was carried out in 4 sessions and each panelist evaluated all processed samples in each session (QDS 27%, QDS 30%, QDS 33% and standard 28 %).

The GLM of SAS version 9.1 (SAS, 1999) procedure was used for the statistical analysis. The data of color, texture and degree of dryness were included in the model as principal factors. The sample was the experimental unit ($P \leq 0{,}05$). The model included the type of *chorizo* (QDS 27%, QDS 30%, QDS 33% and standard 28 %) and the day of the session as fixed effects ($P \leq 0{,}10$). The measurements were compared using the Tukey test.

3.-Results

Fermentation of the sausages caused a reduction in the pH of the *chorizo* of 5.96 ± 0.04 to 4.62 ± 0.07 for the product that had undergone the QDS process® and to 5.18 ± 0.02 for the product that had undergone the standard process. The evolution of the pH of the *chorizo* differed depending on type of drying. During the QDS process® drying, the pH increased slightly from 4.62 to 4.78 in the product with 33% loss (Table 1), while in the standard process the pH decreased from 5.18 to 4.80 due to the product's microbiological development during the long drying process. The effect of weight losses reached with QDS process® on pH significantly increased with weight losses ($P<0.05$) but the differences were small.

Table 1. Averages of the physicochemical, instrumental color data and the relaxation test parameters of the *chorizo* samples processed by QDS at differing weight losses (27, 30 and 33 %) and *chorizo* processed by standard drying (28 % weight loss).

Moisture decreased as the drying loss was increased, as was expected. Likewise, the water activity also decreased, since there is less water available. Color was affected by the moisture content. Table 1 shows a tendency for the values L*, a* and b* to decrease as moisture decreases in the products undergoing the QDS process®. Some studies have reported the effect of moisture content on color. For example, Comaposada, et al. (2009) demonstrated that when moisture was lower, L* decreased, while a* and b* increased in value. Said study was carried out with raw lean meat, without coloring agents added, which could account for the different behavior of a* and b*. Chasco et al. (1996) pointed out that the principal changes in color during processing of sausage took place during the fermentation stage, although the formation of nitrosyl myoglobin pigment continues throughout the entire drying process (4 weeks). This could explain the different values of L*, a* and b* obtained in the *chorizo* dried with the standard process (40 days), which is somewhat lighter, redder and more yellow than that obtained with the QDS process®. Similarly, it can be seen that the color evaluated by panel test is less intense in the *chorizo* processed by standard drying (Table 2).

The differences in color obtained in the dry product is attributed mainly to the degree of drying loss, since the pH differences in the finished product are considered too small.

The variation in the product's appearance can be more easily regulated in the QDS process® than in a standard process, due to a better control of the moisture content and pH, as well as control of the chemical reactions that affect color such as oxidation or reduction of some colorants.

The parameters of the relaxation test (SR) are related to the moisture. F0, Y2 and Y90, increasing when the moisture decreases (Table 1) for the product resulting from the QDS process®. The *chorizo* dried with the standard process shows lower values of toughness, which could be attributed to a certain proteolysis developed during the 40 days of drying.

TABLE 1

	After Fermentation[1]	QDS process®			Standard process 28%	RMSE[2]
		27 %	30 %	33 %		
Moisture (%)	59.8	43.0^{a}	40.2^{b}	39.4^{b}	43.6^{a}	0.504
a_w	0.962	0.904^{a}	0.890^{ab}	0.868^{b}	0.907^{a}	0.010
pH	4.62	4.70^{c}	4.73^{bc}	4.78^{ab}	4.80^{a}	0.030
L*	49.8	45.3^{b}	45.0^{bc}	42.5^{c}	49.0^{a}	1.210
a*	28.9	25.5^{ab}	24.7^{b}	23.9^{b}	26.6^{a}	0.715
b*	17.8	15.3^{a}	14.3^{bc}	13.8^{bc}	19.1^{a}	0.527
F_o (Kg)	1.52	2.90^{a}	3.60^{b}	4.65^{a}	1.83^{c}	0.375
Y_2	0.331	0.318	0.311	0.302	0.310	0.007
Y_{90}	0.670	0.618^{a}	0.313^{a}	0.607^{ab}	0.586^{b}	0.010

a,b Within the same row, the values with a common letter are not significantly different($P \leq 0{,}05$). 1 Not included in the statistic model.
2 Root mean squared error of the linear model

As has been shown by other studies, the SR test can be a good indicator of texture (Morales et al., 2008 and Gross et al., 1980). In the same direction, it can be observed that the sensory hardness (Table 2) tends to increase when the moisture content of the *chorizo* dried with the QDS process® decreases. Also the *chorizo* dried with the standard process tends to be less hard, although the differences are not significant ($P \leq 0,05$) with the QDS process® product with 27 % weight loss. Some differences in the intensity of the *chorizo* flavor can be observed between the product elaborated with the different processes, the flavor of the standard process product being slightly more intense. The elaboration of a QDS process® product showing similar flavor intensity requires an adaptation in the formulation of some ingredients and additives. Although the pH after the fermentation step of the QDS process® product was lower than the final pH of the standard process product, the acid flavor of QDS process® product tended to be less acidic (Table 2). If the final pH after fermentation is similar for both processes, at the end of the drying step, the flavor is significantly more acidic in the standard process product than in the QDS process® product (Comaposada et al., 2007). The QDS process® allows for an easier adjustment of the acidic taste thanks to better control of the process.

Table 2. Averages of some sensory parameters of QDS *chorizo* at distinct weight losses (27, 30 and 33 %) and standard drying process *chorizo* (28 % weight loss).

4.- Conclusions

It's clear that a difference from 27 to 33 % in the weight loss of *chorizo* dried with the QDS process® makes significant differences in the physico-chemical color parameters (L* y b*) and in texture (F0), being darker, less yellowish and harder the drier the product. The *chorizo* quality differences between closer weight losses (27 to 30% or from 30 to 33%) were lower. *Chorizo* elaborated with the standard process shows a higher luminosity (L*) (a lighter and less aged appearance) than the QDS process® *chorizo*, as well as less hardness. The sensory analysis showed tendencies in the same sense as the physicochemical analysis, with flavor and texture aspects slightly best evaluated for the standard process *chorizo*, while the general appearance was better for the QDS process® product. The 40 minutes drying (QDS process®) allows for a better adjustment of the weight loss and the pH evolution than the 40 days drying of the standard process, being easier to mold the appearance and acidic flavor due to better process control.

Benefits of the "QDS process®" technology

Due to the importance of this technology and its recent introduction to the market, it's necessary to emphasize its benefits.
For the sliced product market, the "QDS process®" technology presents a large number of advantages compared to the traditional drying technology for raw cured products. From the technological point of view the "QDS process®" allows for a much better control of the manufacturing process and of the product quality.

TABLE 2

	QDS process®			Standard process 28%	RMSE[1]
	27 %	30 %	33 %		
Color intensity	6.0^{ab}	7.3^{a}	6.0^{ab}	4.8^{b}	0.677
Hardness	4.8^{ab}	5.3^{a}	5.4^{a}	3.8^{b}	0.535
Acidic Flavor	4.9	4.1	4.1	6.2	1.350
Chorizo Flavor intensity	4.7^{b}	4.8^{b}	5.0^{ab}	7.0^{a}	1.058

1. Root-mean-squared error of the linear model.

Factors such as the oxidation and acidity levels as well as the product homogeneity take advantage of the high process speed. In the same way, the accurate control allows for an improvement of the yields and a reduction of waste.
On the manufacturing process side, the energy consumption is notably lower and the methodology offers a great flexibility in production planning as the process is shorter, allowing for a just-in-time workflow that reduces drastically the funds required to finance the stock of drying product. From the point of view of investment, this new technology requires much less space than the traditional system requiring, only drying chambers for the short fermentation process.

The system permits developing new formats other than the traditional round shape and also new products in line with the lifestyle tendencies of today's consumer, which demands ready-to-eat products in small formats. The immediacy in obtaining the finished product allows for the optimization of the development of new products for sensitive communities (hypertensive, aged people, immuno compromised people, diabetics, obese people, etc...) and products that meet the objectives of the NAOS Strategy agreed between the Spanish Administration and the major Spanish food industries promoting the need to reduce the daily intake of fat and salt among others.

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ACKNOWLEDGEMENTS

This study was partially financed through the program Consorcios Estratégicos Nacionales en Investigación Técnica (CENIT) of the Ministerio de Ciencia e Innovación (CENIT-2007-2016-FUTURAL), and by Metalquimia S.A.U. and Casademont S.A.